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IGNITION SYSTEM AND SPARK PLUG

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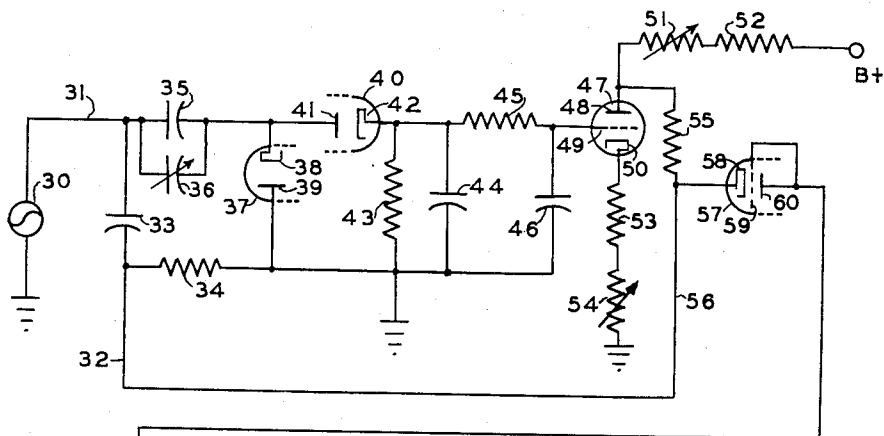


FIG. 2

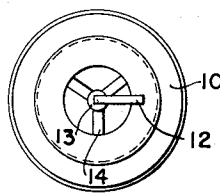
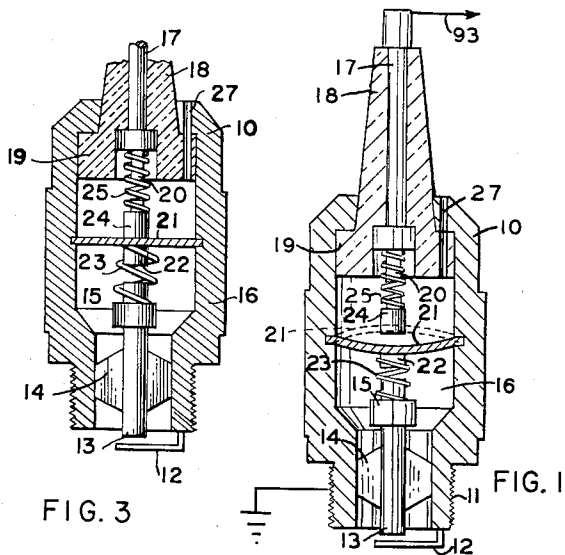
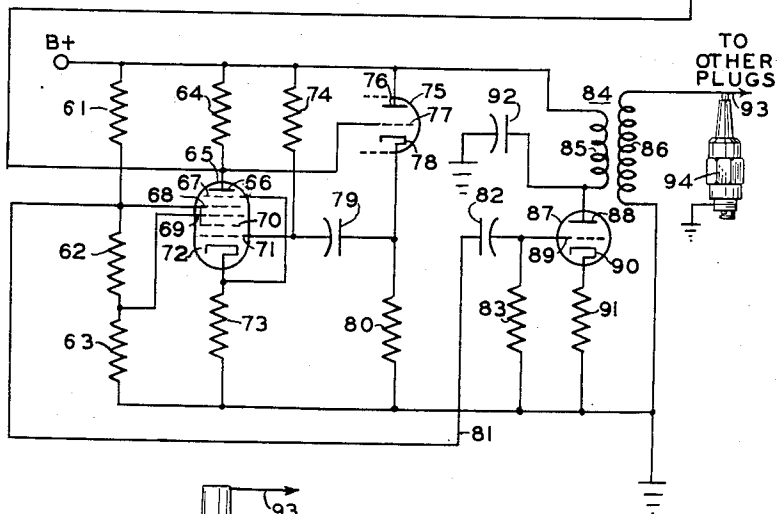


FIG. 4

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1

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IGNITION SYSTEM AND SPARK PLUG

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This invention relates to an ignition system and spark plug for use in connection with the firing of the cylinders of internal combustion engines and is particularly concerned with an electronic energization system for spark plugs together with a pressure responsive spark plug that automatically selects the ignition sequence of the individual cylinders in response to predetermined pressure conditions therein.

Conventional ignition systems for multiple cylinder internal combustion engines, provide an ignition potential which is directed to the individual spark plugs by mechanical distributor means rotatably correlated, along with timing cam and contact means, to the engine crank shaft. Such systems and the spark plugs associated therewith have long been known and have been developed to a high standard of effective and reliable performance.

However, such systems are not ideal in that the potential provided for firing the spark plugs is adversely affected by variations in engine speed. Since the magnitude of high potential depends on the rate at which the distributor cam opens the contacts, or points, to break the primary current in the ignition coil, variations in cam speed affect the opening rate of the points, thereby varying the magnitude of the high potential used for ignition. This condition results in erratic operation of the ignition system, particularly at low engine r.p.m. where the required plug firing potential often is not attained, thereby causing severe vibration.

Another disadvantage of conventional cam timing systems presently in general use is that at high cam speeds the points often fail to close at all, or sufficiently long to allow the primary current in the ignition coil to build up to operational value, resulting in "cut out" at high engine r.p.m.

A further disadvantage of conventional ignition timing systems lies in the fact that in such systems spark advance responds solely to manifold pressure, thereby failing to accurately follow the optimum advance required for maximum efficient operation of the engine throughout its r.p.m. range.

It is therefore among the primary objects of the present invention to provide a novel and improved ignition system and spark plugs therefor which will effectively and efficiently deliver an accurately timed and uniformly peaked potential for firing the individual cylinders of a multiple cylinder internal combustion engine throughout the entire r.p.m. range of said engine.

Another object of this invention is to provide a novel and improved system for the delivery to the spark plugs of an ignition potential whose magnitude is independent of the speed of revolution of the engine.

A further object of this invention is to provide an electronic ignition timing system in which the total spark advance is regulated in combined response to both engine r.p.m. and manifold pressure.

Another important object of this invention is to provide an electronic ignition timing system which avoids

2

the inaccuracies of conventional slow-acting and non-linear mechanical spark advance devices.

A further important object of this invention is to provide a novel and improved spark plug having an internal pressure switch arrangement which actuates closed when the engine cylinder associated therewith reaches an optimum condition of compression.

Still another object of this invention is to provide an ignition distribution system for an internal combustion engine in which the sequence of firing of the engine cylinders is determined by the conditions of compression in said cylinders.

It is also an object of the present invention to provide an ignition timing and distribution system whose performance is a function of manifold pressure, engine r.p.m. and cylinder compression.

Numerous other objects, features and advantages of the present invention will be apparent from consideration of the following specification taken in conjunction with the accompanying drawing, in which:

Fig. 1 is a vertical sectional view of a preferred spark plug for use in connection with the system of the present invention.

Fig. 2 is a schematic diagram illustrating an electronic circuit embodying the present invention.

Fig. 3 is a vertical sectional view of the spark plug shown in Fig. 1 in firing position.

Fig. 4 is a bottom end view of the spark plug shown in Fig. 1.

While the present inventive concept with respect to the electronic circuit may be widely varied and while the components thereof are not individually of themselves deemed to be of patentable significance, the invention as herein disclosed in one of its preferred embodiments may be generally defined as follows: A pulse generator, mechanically correlated with the crank shaft of an internal combustion engine, supplies a series of pulses, each timed to precede by approximately sixty degrees of crankshaft rotation the maximum compression point of each cylinder of the engine. These pulses are fed into two channels, both of which are used to control a phantastron circuit. From one channel the pulses initiate operation of the phantastron whereby a rectangular output waveform begins. From the second channel the pulses are fed into a frequency counter circuit which produces a D.C. output, the level of which is a direct function of input pulse frequency and coupling capacitance. The output of the frequency counter circuit is used as the second input to the phantastron circuit where it controls the duration of the rectangular output waveform. The input level to the phantastron circuit is so pre-adjusted that the trailing edge of phantastron waveform is an equivalent sixty degrees of crankshaft rotation lagging the pulses from the pulse generator and therefore are timed in synchronism with the point of maximum compression of each cylinder. Differentiation of the phantastron output waveform provides a negative pulse at the trailing edge, which is used to interrupt the primary current in the ignition coil and thereby generate a high secondary potential. Fed in parallel to the spark plugs, this high potential fires only that plug whose associated cylinder has reached the optimum compression required to close a pressure responsive switch therein.

Since manifold pressure controls the coupling capacitance of the frequency counter circuit and engine r.p.m. controls the frequency of input pulses, as can be seen, changes in either manifold pressure or engine r.p.m. reflect as a change in the duration of the phantastron output waveform, thereby controlling the ignition timing of the engine. Distribution of the ignition potential is effected by the novel compression responsive spark plug used herein.

For a more complete understanding of the invention, reference is now made to Fig. 1 depicting one preferred embodiment of the structure of the spark plug of the present invention.

It will be seen that the spark plug has a conventional body 10 having an externally threaded neck 11 to be threadedly engaged in the cylinder head of an otherwise generally conventional internal combustion engine. The externally threaded neck portion 11 of the body 10 is formed of conductive material to provide a grounding connection with the motor block and to provide a conductive path therethrough to the grounded terminal or electrode 12 of the plug. The opposed and spaced electrode 13 of the plug is of generally conventional rod-like construction being mounted within the neck 11 and spaced therefrom by the usual ceramic or other dielectric member as indicated at 14. As distinct from conventional spark plugs, however, the central electrode 13 extends only partially upward in the body 10 terminating at a point 15 within a central diaphragm chamber 16 within the body 10. In spaced axial alignment with the electrode or conductor 13 there is provided an upper electrode 17 mounted within a suitable ceramic or otherwise dielectric body 18, the enlarged head 19 of which is seated in the upper end of the chamber 16. The upper electrode 17, as distinct from the normal spark plug, terminates at a point 20 vertically spaced in the chamber 16 upwardly from the upper terminal end 15 of the lower electrode 13. In the chamber 16 there is mounted a transversely disposed diaphragm 21 which is pressure responsive and which in its full lower convex position, as shown in Fig. 1, indicates a pressure condition within the cylinder lower than that of the ideal pressure condition for firing in full lines, and in broken lines the diaphragm is shown in a pressure condition within the cylinder higher than that of the ideal pressure condition for firing; whereas, Fig. 3 indicates a pressure condition within the cylinder suitable for firing, and it will be understood that the cylinder pressure reaches the diaphragm 21 by the gases passing through the neck 11 and past the spacer member 14. The lower surface of the diaphragm engages a spring mounted contact 22, the spring 23 of which encircles and electrically engages the lower electrode 13. In such position, however, the downwardly directed convex character of the diaphragm moves the central surface thereof away from the upper contact 24, mounted on the spring 25 encircling and electrically associated with the upper electrode 17. Hence, with the diaphragm in this position, electrical communication between the contact 24 and the diaphragm is broken and a very high impedance will result, so that application of ignition potential to the upper electrode 17 will have no effect. In the opposite upward convex position of the diaphragm 21, which reflects a pressure in the cylinder above that of the ideal firing position, the diaphragm will be fully in contact with the contact 24 but such flexing will remove the lower central surface of the diaphragm 21 from the lower contact 22 and hence the line of potential to the lower electrode 13 will be broken, thereby presenting a very high impedance to the flow of current. Hence, no firing of the cylinder will result, in spite of the application of potential to the electrode 17, when the pressure condition of the cylinder is such as to flex the diaphragm into its extreme upward position.

However, when the ideal pressure conditions are achieved within the cylinder the diaphragm 21 will assume a substantially parallel transverse position in the chamber 16; in which position, the springs 23 and 25 will urge both contacts 22 and 24 into electrical engagement with the conductive disc 21. In such circumstances, when potential is applied to the electrode 17, it will pass through the springs and contacts as well as through the diaphragm 21 to provide an appropriate

difference of potential between the points 13 and 12 to ignite the fuel within the cylinder. A small air passage 27 is provided through dielectric member 19 and body 10 so as to prevent pressure build-up from combustion gases that may be forced past diaphragm 21.

While the structure of the spark plug as here presented will effectively and efficiently provide an electrical distribution between spark plugs, it is to be understood that the invention is not limited or confined to the exact structural details herein presented. Other pressure responsive means may of course be provided by which the timing of the cylinder ignition is affected. Thus, while the present invention partakes of the structural features of the spark plugs herein presented, it will be understood that the ignition system of the present invention while ideally arranged for the use of spark plugs of the type presented is not to be construed as limited or confined to the particular structural features of the preferred embodiment herein disclosed.

Referring now to the proposed electronic system depicted by the schematic wiring diagram of Fig. 2, the numeral 30 designates a pulse generator of conventional form adapted to be driven by and with the crank shaft of the engine or otherwise in synchronism with the speed of rotation of the engine. Pulse generator 30, for example, may be a sine wave generator feeding into a suitable pulse shaping circuit having grid and plate limiting, or may be a simple microswitch arrangement. Resultant positive pulses, varying in repetition rate with engine r.p.m., are applied to the input of the frequency counter functioning as a pulse rate to D.C. level converter, having numerical designators 35 through 54. The charge on the coupling capacitors 35 and 36 cannot change instantaneously as the positive leading edge of a pulse is applied; so the plate 41 of diode 40 becomes positive and the diode conducts. A charging current flows through resistor 43 during the pulse time and a small charge is developed on capacitors 35 and 36. At the end of the pulse the drop in voltage places the diode side of the coupling capacitance at a negative potential equal to the charge accumulated on capacitors 35 and 36. Diode 40 cannot conduct, as its plate is negative with respect to its cathode. However, diode 37 conducts, discharging the small charge from capacitors 35 and 36, which would otherwise build up during each succeeding positive pulse, eventually rendering the circuit insensitive to the applied pulses. Since a certain amount of current flows through resistor 43 each time a positive pulse is applied, an average current flows which increases as the pulse repetition rate increases and decreases as the pulse repetition rate decreases. The IR drop developed across resistor 43 is filtered by means of capacitor 44, resistor 45, and capacitor 46 to remove rapid changes in voltage developed across resistor 43, thereby obtaining an average D.C. voltage level. This average voltage, applied to the grid 49 of amplifier tube 47, varies with changes in pulse frequency, and produces amplified variations at the plate 48 of the tube 47, which is supplied from B+ through a plate load consisting of resistor 52 and rheostat 51. The cathode 50 is connected to ground through cathode resistor 53 in series with rheostat 54. The range of plate voltage variation can be present to the proper reference level by adjustment of plate rheostat 51 and cathode rheostat 54.

Trimmer capacitor 36, connected in parallel with capacitor 35, is mechanically controlled by the engine vacuum advance, thereby increasing and decreasing the coupling capacitance in proportion to manifold pressure changes. This variation in coupling capacitance reflects a like variation in charging time through resistor 43, thereby effecting control of the average D.C. level to the grid of tube 47, independent of the pulse repetition rate.

The output from the frequency counter circuit, taken from the plate 48 of the amplifier tube 47 as a D.C. level, functions as the control signal for the phantastron

circuit, having numerical designators 55 through 80. The phantastron circuit is capable of generating rectangular waveforms whose duration is a linear function of this control signal. Synchronous operation of the phantastron with engine r.p.m. is accomplished by differentiation of the pulses from pulse generator 30 to obtain triggering pulses for the phantastron.

The phantastron circuit centers about tube 65, which is a heptode having five grids, being commercially available as type 6SA7. Suppressor grid 67 is connected to cathode 72, which is grounded through cathode resistor 73. Screen grids 68 and 70 are internally tied together and receive operating potential from the voltage divider, consisting of resistors 61, 62 and 63, joined in series between B+ and ground, which also supplies proper operating potential on grid 69. The plate 66 of heptode 65 is connected to B+ through plate load resistor 64. The D.C. level input to the circuit is taken from plate 48 of amplifier 47 through resistor 55 to the cathode 58 of the diode connected triode 57, which has its grid 59 tied to its plate 60. From the plate 60 of triode 57 connection is made to the plate 66 of the phantastron tube 65, and from there to the grid 77 of tube 75. The tube 75 is cathode follower connected, having its plate supplied directly from B+, and its cathode connected to ground through cathode resistor 80. The output from the cathode follower is coupled from its cathode 78 through capacitor 79 to control grid 71 of tube 65, which also is connected to B+ through resistor 74.

In operation, a negative pulse from differentiating circuit 33, 34 is applied to the cathode 58 of diode connected triode 57 through conductor 56. This triggering pulse momentarily changes the plate current in the diode, which causes a negative pulse to appear at the plate 66 of the phantastron tube, which is coupled to the grid 77 of the cathode follower 75 thereby reflecting a drop in the voltage at its cathode 78. Before the trigger pulse arrives, the grid of the cathode follower is at the potential of plate 66 and therefore drawing current, with its cathode voltage following within a fraction of a volt. When the trigger pulse drops the voltage at cathode 78, the capacitor 79 must discharge, and in doing so, makes grid 71 of the tube 65 go in a negative direction, thereby starting the phantastron through its cycle of operation. The negative going grid 71 decreases the total current slightly; but the resultant decrease in cathode voltage, lowers the voltage between screen grid 69 and cathode 72, which allows current to flow to the plate 66 at the expense of screen current, thereby increasing the plate current. Grid 69 controls the division of current between the plate and screen grids 68 and 70, whereas grid 71 controls the total amount of current. So grid 71 decreases the total current slightly, while grid 69 allows the plate current to increase and causes the screen current to decrease quite rapidly. The plate voltage drop resulting from this plate current increase, has an effect opposite to that of the discharging condenser and thereby is degenerative in action. The plate voltage change, however, only counteracts part of the capacitor discharge, slowing the discharge considerably. When the plate current levels off, as determined by the D.C. level input from the plate 48 of triode 47, the voltage stops decreasing at the plate 66. With the counteracting effect of the plate removed, the capacitor discharge raises the grid 71 at a very rapid rate, to initiate a regenerative "turn-off" action. The positive going grid 71 increases the current from the cathode, which raises the cathode voltage. This has the same effect as making the grid 69 more negative, so as to reduce the current to the plate. Actually, it is dividing the increasing current in favor of the screen grids. This regenerative action continues until grid 69 is beyond cut-off, thereby stopping plate current completely. As the voltage at the plate 66 approaches B+, the cathode 78 of tube 75 follows and

the capacitor 79 quickly charges through a path from cathode 72 to grid 71, through capacitor 79, from the cathode to the plate of the cathode follower, to B+, thereby returning the phantastron circuit to pretrigger condition.

The rectangular output waveform from the phantastron circuit, taken from screen grid 68 of tube 65, by conductor 81 is differentiated by capacitor 82 and resistor 83 and then used as the input to triode 87. The plate 88 of triode 87 is connected to B+ through the primary 85 of ignition coil 84, the secondary of which is connected with one side to ground and the other side to the spark plugs of an internal combustion engine by wire 93. The cathode 90 of the tube 87 is connected to ground through cathode resistor 91. A capacitor 92 is connected from the plate 88 of the triode 87 to ground.

Differentiation of the phantastron output waveform produces a positive pulse at the leading edge and a negative pulse at the trailing edge, both of which are fed onto the grid 89 of triode 87. The positive pulse, in phase with the pulses from the pulse generator 30, has no effect on the operation of the triode 87 since the tube is operating at plate current saturation. However, the negative pulse, having a nominal reference delay of sixty degrees for top dead center firing of the spark plugs, sharply cuts off the plate current of the tube 87, forcing a collapse of the magnetic field of the primary winding 85, whereby a high secondary voltage is generated. This high voltage is fed in parallel to all the spark plugs, generally designated as at 94, firing only that plug which has attained the ideal firing condition, as heretofore described. Capacitor 92 prevents arcing in the tube 87, and effects an oscillation in the primary winding of the ignition coil, effecting a short series of high voltage pulses to insure complete ignition of the combustion mixture.

Thus in the operation of the engine it will be seen that at the approximate time of the ideal pressure condition within any cylinder for the ignition thereof, all of the electrodes 17 of all of the spark plugs will be supplied with the desired ignition voltage. However, since only one cylinder is at the ideal pressure condition for ignition with its spark plug diaphragm disposed in the intermediate position establishing a conductive path from the upper electrode 17 to lower electrode 13, only that one cylinder will have its charge ignited by the passage of the potential across the spark plug gap formed between the electrodes 12 and 13.

From the foregoing it will be seen that the present invention provides, in addition to a novel and improved spark plug the ignition of which is permitted only during a predetermined pressure condition within the cylinder, an electronic timing circuit in which the total spark advance is regulated in combined response to both engine r.p.m. and manifold pressure.

In carrying out the present invention it will be understood that circuit modifications and equivalent components may be utilized without departing from the spirit or scope of the invention; and similarly, the invention is not limited to specific design or construction features depicted with respect to the spark plug here presented. Therefore, numerous changes, modifications, and the full use of equivalents may be resorted to in the practice of the invention without departure from the spirit or scope as outlined in the appended claims.

I claim:

1. In a spark plug, a potential input conductor, a first electrode forming a first firing point, a second electrode forming a second spaced firing point, and circuit control means between said input conductor and said first firing point, said means comprising a pressure responsive device in the form of a transverse diaphragm, said diaphragm being movable toward and away from said input conductor to make and break a circuit between said input conductor and said first firing point.
2. In a spark plug, a potential input conductor, a

first electrode forming a first firing point, a second electrode forming a second spaced firing point and circuit control means between said input conductor and said first firing point, said means comprising a pressure responsive device in the form of a transverse diaphragm and spring mounted contacts on said conductor and first electrode engageable with said diaphragm.

3. In a spark plug, a potential input conductor, a first electrode forming a first firing point, a second electrode forming a second spaced firing point and circuit control means between said input conductor and said first firing point, said means comprising a pressure responsive device in the form of a transverse diaphragm and spring mounted contacts on said conductor and first electrode engageable with said diaphragm, both of said contacts being engageable with said diaphragm when said diaphragm is in an intermediate position in response to a pressure condition within the cylinder intermediate maximum and minimum pressure.

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